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A Preliminary Study of the Causes that Produce "Bald-headed" Kelp.

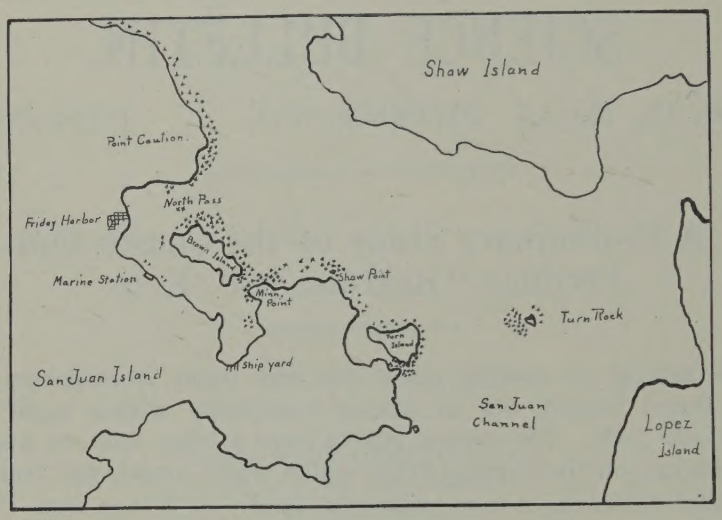
BY RUPERT PETERS.

IN sailing or rowing about the San Juan Archipelago in Puget Sound, one is almost constantly within sight of the kelp beds. The typical plants have a large float, or pneumatocyst, on the surface from which many broad, flat fronds stream outward, in many cases for twelve or fifteen feet. Yet among these plants are many that have lost part or all of their fronds, and the rounded shiny pneumatocyst bulb suggests the term "bald-headed." Since the kelp is recognized as a source of potash for agricultural fertilizers, the loss of a considerable per cent of the fronds reduces the weight that might be harvested very seriously, over two-thirds in many cases.

This subject was suggested to the writer by Dr. R. B. Wylie of the University of Iowa, a member of the U. S. kelp investigation staff during the summer of 1913, following a considerable discussion of the kelp, *Nereocystis luetkeana,* and as full a statement as he was at liberty to give concerning the work being done by that staff. These obesrvations were made in connection with work at the Puget Sound Marine Biological Station, June-August, 1913. It is to be regretted that observations did not begin early in the term, since many plants were without fronds when observations began, while others were still in vigorous growth.

Facilities for getting from place to place were limited and the observations were confined almost entirely to the neigh-

borhood of Friday Harbor, on the east coast of San Juan Island. In the accompanying sketch map the location of most of the observations made is approximately indicated, the crosses showing roughly the location and density of the kelp beds.



Since the tide currents play an important role in the distribution and health of *Nereocystis,* a brief description of their location and strength in the neighborhood is in place. The incoming tide sweeps through the narrowed channels on either side of Turn Rock with great velocity, so much so that landings can be made there at the turn of the tide only. A branch of this current, much weakened, sweeps in south of Turn Island and around the west side. This results in the north side of the island being sheltered. The current going north to Shaw Point is not strong toward the shore, but at that point the two currents unite and sweep around it with considerable velocity. The bay between Shaw Point and Minnesota Point is sheltered. Near the latter cape the current usually divides, one branch continuing on through South Pass into Friday Harbor Bay, the other and far the stronger turning north along the east side of Brown Island. The former sweeps around through the bay and out of North Pass to join the latter at Point Caution, where they form a stiff current that hugs the shore closely for some distance to the north. With the ebb tide the directions of the currents are reversed.

With this in mind an inspection of the map shows the heaviest growth of kelp along the edges of the strongest currents, a fact already discussed by Frye, Setchell, Rigg, and others. The conditions for its growth do not belong here and have been already discussed by Professor Rigg.[1] But the currents play too important a part in this problem to be left unnoticed.

The bald-headed kelps which were under observation had lost part or all of their fronds. Usually there was a stump left of each which showed a whitened, slimy, apparently half-putrid end. (Fig. 1.) Relieved of the pull of the fronds the floats stood upright several inches out of the water, in sharp contrast to their healthy neighbors. (Fig. 2.) In many cases the side of the bulb had become flattened and wrinkled, in some cases decaying. The flattened, decaying condition was noticed in healthy plants as well, however. In the case of the latter, *i. e.*, those with a full set of fronds, this may be the result of mechanical injury, but the writer is inclined to think it due to sunburn resulting from a few hours' drying when held out of the water by neighboring plants. With the "bald-heads" it is an indication of the death of the plant, since it soon dies after losing its fronds, as proven by Zeller's experiments in 1911.[2]

The first thing to attract attention when the observations were begun was the snails, *Lacuna sp.*, present in large numbers upon many plants. The eggs were laid in jelly-like capsules, usually upon the bulb of the pneumatocyst or the bases of the fronds. The writer found them upon all parts of the plant, however, in one case a capsule upon the hapteres pulled from a depth of 39 feet. But the favorite location is as indicated above. (Fig. 3.) In feeding the snails eat the epidermis and perhaps the first cell layers beneath. As the meristem region is youngest and presumably tenderest, or perhaps because it is exposed to the air, it is the region most frequently chosen for a meal. Doctor Setchell[3] says, "The central or medullary tissues are made up, as a rule, of elongated—often tubular—cells and have for their function the conduction of substances manufactured and distributed from the outer

1. Professor Rigg, Bul. P. S. Marine Sta. Notes on the Ecology and Economic Importance of *Nereocystis luetkeana*.

2. Professor Rigg, Fertilizer Resources of the U. S., Appendix L.

3. Doctor Setchell, same, Appendix K.

tissues. They are destitute of assimilating cell organs, the chromatophores or chlorophyll granules. The outermost layers are composed of smaller cells, nearly isodiametric, which contain the chromatophores and are consequently the assimilating tissues." This led the writer to question the effect of these masses of eggs on the meristem region; could they cut off light enough to interfere with growth or enough to weaken the cells to the point that the fronds would drop off at that point?[4] A large number of observations were made off the east side of Brown Island, several plants which had most of the meristem region covered by egg clusters being under observation for over three weeks. No change could be discerned and the fronds seemed as tough at the close of the period as at the beginning. Professor Rigg's[5] statement that "the region of elongation in this plant extends over the pneumatocyst and the bases of the fronds" has since come to notice and explains the failure to get results. The egg masses were over the bases of the fronds and the top only of the pneumatocysts, leaving most of the "region of elongation" exposed.

At the same time as the above, observations were made to determine the effect of the scorings made when the snails fed. (Fig. 4.) Three healthy plants were selected and tagged. The cuticle was scraped with a knife blade from one side of the base of one cluster of the fronds of the first, from one side of both clusters of the second, and from both sides of both clusters of the third. A fourth was freshly snail-eaten at the same point, the animal having been brushed off in order to see the extent of the damage. These four plants and others were under observation for a month. The cuts did not seem to weaken the fronds in the least. No breaks came and they were healthy until the snails ate them up, that is, peeled so much off in large spots that the fronds were weakened and broke off in fragments. (Fig. 5.) The failure to get positive results from the experiments and from the observations of the snail's feeding habits with this one point in mind nevertheless gave positive evidence as to the loss of fronds in some plants. On the thick beds where the snails were abundant, they ate the fronds in holes, weakening them so that they broke off in large pieces. The snails seemed to retreat before the im-

4. Since the above was written, Doctor Wiley has suggested that the interference with gaseous exchange by the excretions of the snails might be of more importance than this interference with light relations.

5. Professor Rigg, Fertilizer Resources of the U. S., Appendix L.

pending loss and to continue eating toward the base until the whole frond was gone. The appended table of some observations gives color to this conclusion.

From the table it is seen that the snails are found on the kelp where the current is weak, that in these places many plants are without fronds, that the kelp in the strong currents have relatively few without fronds and that where they do occur they are in clustered groups, and that where the plants are scattered and in strong currents they are uniformly healthy.

In observation No. 23 the plants were against the shore, so that as the tide ebbed and flowed they were swept back and forth across the rocks. This may account for some being without fronds. The same condition was noticed along the east side of the island and also off Point Caution. The plants next the shore were nearly all frondless. In each of these cases the shore is abrupt. South of Turn Island the shore is gently sloping and the plants there, similarly placed to those in the places just mentioned, were healthy.

Yet these observations have not accounted for the numbers of bald-heads in the strong currents. Drifting back to the Station after making observation No. 26, the writer's attention was caught by some fronds in the thick clusters west of Shaw Point which had been thrown up over the floating pneumatocysts of neighboring plants and, exposed to sun and wind, had become discolored and dry. However, they were not crisp enough to break. Yet this suggested a new factor and it was late when the Station was reached. Several like cases were found that evening. The field from below Turn Island to Point Caution was resurveyed with this point in mind and thirty-six similar cases found, all being of plants in the center of thick clumps. Some were so crisp as to break off like dead leaves when handled. Unfortunately, bad weather prevented watching these closely. So in the quiet water near camp a fine healthy plant was selected, exposed to tide currents and the wash from every passing vessel. A rude raft of boards was built about it and the fronds were thrown up over this in the same manner as had been observed in the field. A few were left floating as a check. On account of the wash from vessels it was very difficult to keep them as desired without tying the fronds themselves, which would have introduced a

new factor. Yet on the third day the exposed fronds were discolored and soon became crisp, although somewhat leathery. Some were placed back in the water to determine if they would regain their former elasticity. Absence from camp prevented observations for three days, but at the close of this time the fronds had broken off to within eight inches of the pneumatocyst and their ends showed the characteristic white, decayed appearance to be found on all bald-heads. (Fig. 6.) The check fronds seemed as healthy as ever and the dried ones that had been returned to the water had broken off, save one, and it broke when an attempt was made to lift it. It is to be regretted that time did not permit a further test and that the weather prevented field observations; however, it is very suggestive as to the causes of the bald-heads in Nos. 4, 15, 11, 19, etc.

In the quieter waters, the upper portion of the stipe and the pneumatocyst of many plants were found covered with a dense growth of *Ulva fasicata,* this appearing on a greater number of plants each week as the season progressed. So far as could be determined it caused no injury to the plants, even though they were sometimes fairly hidden by it. *Enteromorpha* was frequently found in the same situation. *Antithamnion americana* and *Porphyra nereocystis* were common on the deeper part of the stipe. Various *Rhodophyceæ* shared the holdfasts with many specimens that were pulled up. Other browns were often attached to the same stones as were the *Nereocysti.* In the quieter waters the stipes and pneumatocysts were slimy with a heavy growth of diatoms. Many fronds were spotted with the colonies of a Bryonzoan, *Membraniphora membranceæ,* in many cases almost hidden by its white spots. (Fig. 7.)

None of these, however, seem to cause the damage. So far as observations have gone, the loss of the fronds is due to (1) being eaten off and weakened by the snails; (2) to the drying action of sun and wind when cast up over other plants by the waves and currents and so exposed; and possibly (3) to friction against the rocky shores. It is recognized that these are

but tentative answers to the problem. A longer period of observation and through a whole season, as well as over a larger territory, is necessary to verify or disprove these conclusions.

NOTE.—The writer has spent three seasons at the Puget Sound Marine Biological Station as a member of the Kansas party led by Professor W. J. Baumgartner of the State University. To his unselfish interest the opportunity for the above work was largely due.—R. P.

Number and Location.	Current.	No. of Plants.	Grouping.	Number bald.	Snails.	Remarks.
1—East of Brown Island	Strong	28	Scattered	None	None	A few Bryozoa.
2—East of Brown Island	Strong	21	Scattered	None	None.	
3—East of Brown Island	Strong	12	Scattered in deep water	None	None	Fine specimens.
4—East of Brown Island	Strong	53	Close cluster	7 in center of group	None.	
5—East of Brown Island	Weak	64	Scattered	22, with 30 others badly eaten	Many.	
6—East of Brown Island in sheltered cove	Weak	188	Scattered	168	Many	Not an injured plant in the cove.
7—Cove, False Bay	Weak	46	Crowded	18	Many.	
8—Outside No. 7	Strong	97	Crowded	None	None.	
9—See note below.						
10—East of Minn. Point	Strong	4	Scattered in deep water	None	None.	
11—East of Minn. Point	Strong	43	Crowded	9 in center of group	None	Fine plants; none sick; but the bald in the center.
12—East of Minn. Point	Strong	26	Scattered	None	None.	
13—East of Minn. Point	Strong	3	In deep water	None	None.	
14—East of Minn. Point	Strong	5	In deep water	None	None.	
15—North of Minn. Point	Strong	67	Close clump	11 in center	None	Similar to No. 11.
16—West of Minn. Point	Weak	122	Scattered	69 on shore side, with 42 others badly eaten	Many	Little current on shore side.
17—West of Shaw Point in bay	Little	131	Scattered	81	Few	Shallow water.
18—North of Shaw Point	Strong	178	Dense cluster	16	None.	
19—East of Shaw Point	Strong	87	Crowded	11	None	Many plants kept under by the strong current.
20—See note below.						
21—South toward Turn Island from Shaw Point	Moderate	53	Scattered	3	Few.	
22—North of Turn Island	Weak	22	Scattered	None	None	Out from shore.
23—North of Turn Island	Weak	41	Scattered	28	None	Against shore.
24—South of Turn Island	Moderate	28	Crowded	4	None.	
25—South of Turn Island	Moderate	73	Crowded	8	Few.	
26—West of Turn Rock	Strong	164	Crowded	2	None	The prettiest kelp bed seen.
27—North of Brown Island middle of North Pass	Strong	38	Scattered	None	None	Kept under water most of the time.
28—South of Point Caution	Weak	81	Crowded	65	Many	Snails found even on the hapteres.

29—South of Cattle Point toward the Salmon Banks were a great number of single plants in tide currents so strong as to keep them almost constantly under. These were, without exception, healthy plants.

30—A similar condition to that in No. 29 existed across the channel north of Anacortes.

31—At the west opening of the passage between Orcas and Shaw Islands a clump is swept to and fro by the changing tide currents; the plants are big and healthy; no snails.

9—From False Bay Cove to Kanaka Bay is a dense growth with a strong current outside and a weak one next the shore. Near shore were many plants with fronds missing and with many snails. Outside, very few blades were missing and snails were not to be found.

20—The condition east of Point Caution is practically the same as in No. 9, save that the growth of kelp is not nearly so extensive.